COMMONWEALTH OF AUSTRALIA

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Warning

CHARLES DARWIN UNIVERSITY

Family Name	
Given Names	
Student Number	
Teaching Period	Semester 2, 2015

FINAL EXAMINATION	**DURATION**
ENG142 – Concepts of Chemical Engineering	Reading Time: **10** minutes Writing Time: **180** minutes

INSTRUCTIONS TO CANDIDATES

1. Do not commence writing until instructed to do so.
2. The examination has four questions.
3. The questions ARE NOT of equal value.
4. All questions have to be answered in the answer booklet provided.
5. All questions have to be answered in accordance with the solution strategy.
6. Detailed working in algebraic form is required.
7. Read questions carefully.

EXAM CONDITIONS

This is an OPEN BOOK examination

Any non-programmable calculator is permitted

Any handwritten material is permitted

Any hard copy, dictionary is permitted (annotated allowed)

Answer on the supplied examination material/s only

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
Any printed material with the exception of CDU Library books	1 x 20 Page Book

THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

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Question 1. **(25 Marks)**

Human serum albumin (66.5kg/gmol) is responsible for regulation of human blood composition and is produced exclusively in the liver. Its normal concentration in human blood plasma is in the order of 35-50g/L. In albumin-deficient patients such as those with liver problems, synthetic albumin is used in the form of an aqueous solution with the concentration not higher than 40g/L. This solution also contains in the order of 150mmol/L of sodium chloride (NaCl).

Suppose you need to produce 100L of synthetic albumin solution from a mixture containing 330μmol of albumin and 7.7g of NaCl per every 500.0g of water. One way of achieving this is by using a chromatography column, a very long tube with a very small internal diameter packed with a material which restricts the flow of molecules. Some molecules penetrate through the material faster than the others so that given the appropriate time, the composition at the outlet is different from the composition at the inlet. Assume that only water contributes to the volume, and 80% of water has gone through by the time you obtained the correct solution.

a. Develop a complete block flow diagram of the separation process. (5 Marks)
b. Calculate a full material balance of the process and check that it converges. (15 Marks)
c. Calculate the mass composition of the waste. (5 Marks)

Hint: is there accumulation? where is the waste on the diagram?

Question 2. **(20 Marks)**

Formaldehyde (CH_2O) is an important pre-cursor in the production of resins, polymers, plastics and some fabrics. In an industrial process, it is produced using the following reaction:

$$CO_2 + H_2 \rightarrow CH_2O + H_2O$$

An aqueous solution of CO_2 with a concentration of $1.81\ {}^{g}/_{L}$ is introduced into the reactor at a rate of $1m^3$/hr; and the hydrogen flow rate is 0.114 kg/hr. As a result, 0.7kg/hr of formaldehyde is obtained.

a. Develop a complete block flow diagram of the process and balance the reaction if it is not balanced. (5 Marks)
b. Calculate the molar concentration of the components (excluding water) in the outlet stream. Assume that only water contributes to the volume. (15 Marks)

Question 3. **(25 Marks)**

There is a growing concern about the increase of carbon dioxide levels in the atmosphere. As a result, numerous research groups are looking for ways to capture and reduce the CO_2 from the atmosphere. One of the newest achievements in this area is the development of a catalyst which allows for the production of methane from CO_2 and hydrogen. Water is a by-product of this reaction.

The reactants are pre-mixed before entering the reactor such that the flow rate of CO_2 is 3kgmol/hr, and the flow rate of hydrogen is 8kgmol/hr. The reactor is kept at atmospheric pressure and temperature, at which 2kgmol/hr methane is produced. Heats of formation of each component are in the table below.

Compound	CO_2	H_2	H_2O	CH_4
Heat of formation, kJ/mol	-393.250	0	-241.835	-74.848

a. What is the volumetric flow rate of the reactant stream and how does this compare with the volumetric flow rate of the gas phase in the outlet? *Hints: use the balanced equation of the reaction. In what form does the water exist at the reaction conditions?* (10 Marks)

b. Do you need to add or remove heat to keep the reactor at a constant temperature? How much? (5 Marks)

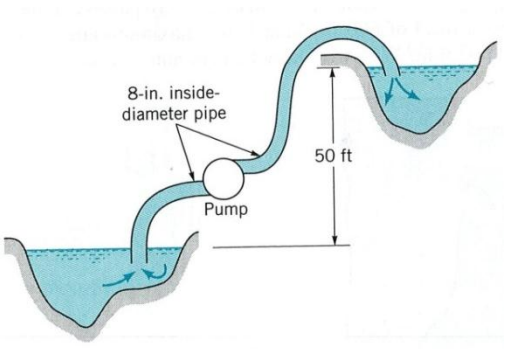
c. The reactor is equipped with a water jacket to keep it at constant temperature. Develop a diagram to demonstrate what mechanisms of heat transfer are present in the system. (5 Marks)

d. At what temperature should the water be maintained if the overall heat transfer coefficient is 5.8J/($m^2 \cdot {}^oC \cdot s$) and the total heat transfer area is $15m^2$? (5 Marks)

Question 4. **(20 Marks)**

Water is to be moved from one reservoir to another as shown in the figure to the right. The loss of available energy due to friction associated with the 2.5 ft^3/s flow rate is:

$$\text{Head loss} = 2.8v^2 \ m^2/s^2$$



where v is the average velocity of water in the 8" pipe.

a. What are the units of velocity in the above equation for the head loss? (2 Marks)

b. What reference positions will you choose and why? (3 Marks)

c. Determine the amount of shaft power required. (15 Marks)